

ϕ -Meson Production at RHIC Energies using the PHENIX Detector

Deepali Sharma

for the PHENIX collaboration.

7th October, 2008



Outline

1 *Motivation*

2 *The PHENIX detector*

3 $\phi \rightarrow K^+K^-$ and $\phi \rightarrow e^+e^-$

- ϕ spectra
- Yield and Temperature

4 *Elliptic flow*

- v_2 of Baryons and Mesons
- v_2 of ϕ

5 *Nuclear Modification Factor*

- R_{dA} and R_{AA}

6 *Summary*

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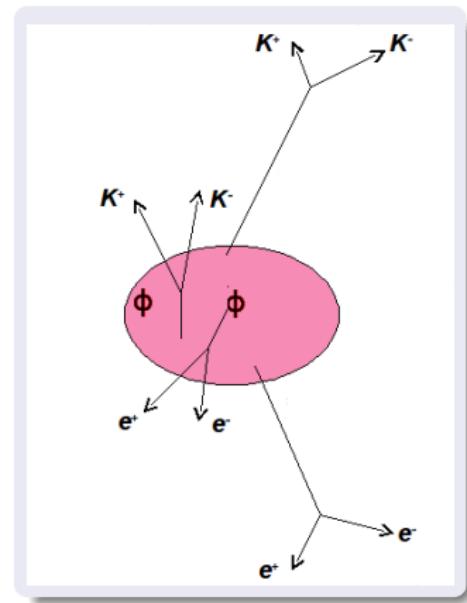
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Motivation

ϕ -meson, a unique probe

ϕ is lightest ($s\bar{s}$) vector meson

- Its production is OZI suppressed in p+p collisions.
- Small cross-section with non-strange hadrons, lifetime $\tau \sim 46\text{fm}/c$.
 - carries information from the early partonic stages of the system evolution.
- A diagnostic probe to Chiral Symmetry Restoration that can manifest itself in:
 - line shape(peak position and/or width) modifications. $\tau_\phi = 46\text{fm}/c, \tau_{QGP} = 10\text{fm}/c \Rightarrow$ only a small fraction of ϕ decays inside the fireball producing a very small modification in the line shape(tail at lower masses).
 - change in the BR of the ϕ decay through e^+e^- to the K^+K^- decay channel.
- Comparable in mass to Λ, p baryons, so its v_2 and R_{cp} provide a critical test for mass or meson/baryon or quark content dependencies and an insight into particle production mechanisms.



PHENIX measures ϕ through both e^+e^- and K^+K^- decay channels.

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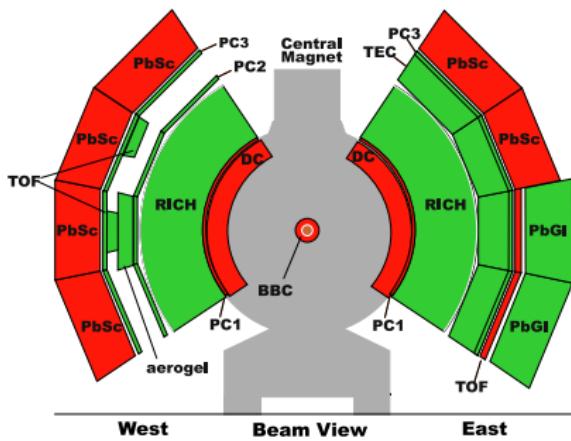
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The PHENIX detector

PHENIX Central arms Acceptance:

$$-0.35 < \eta < 0.35,$$

$2 \times 90^\circ$ for two arms



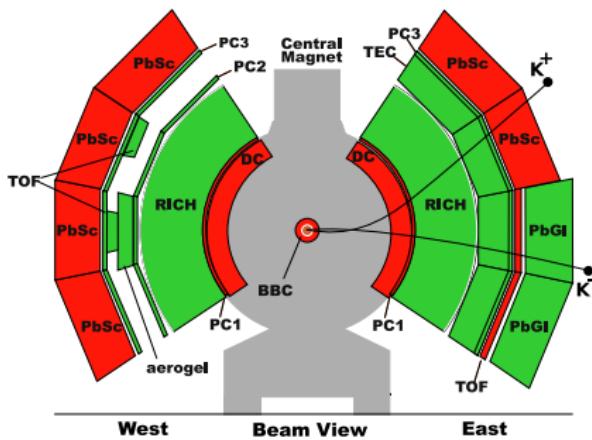
- Vertex: **BBC**
- Tracking: **DC/PC1**
- Matching: **PC3**
- Trigger:
 - Min. bias: **BBC**
 - e: **RICH, EmCal**
- h ID: Time-of-flight
 - **TOF** $d\tau \sim 100$ ns
 - **EmCal** $d\tau \sim 500$ ns
 - **Aerogel** $d\tau \sim 500$ ns
- e ID:
 - Čerenkov light **RICH** (e/π rejection >1000)
 - E-p matching **EmCal** ~ 10

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Measured decays of ϕ

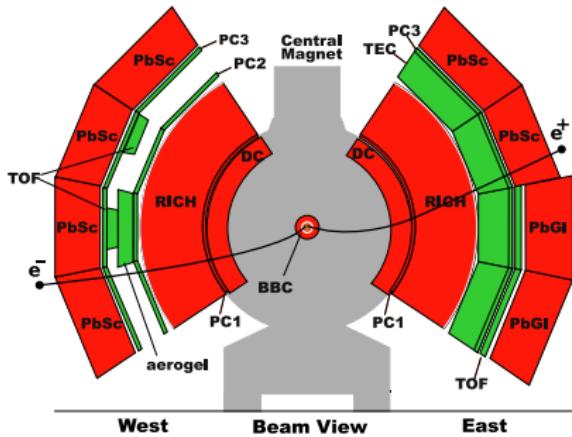
- $\phi \rightarrow K^+ K^-$: BR = $49.2 \pm 0.7\%$

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Measured decays of ϕ

- $\phi \rightarrow K^+ K^-$: **BR** = $49.2 \pm 0.7\%$
- $\phi \rightarrow e^+ e^-$: **BR** = $(2.97 \pm 0.04) \times 10^{-4}$

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$\phi \rightarrow K^+K^-$ *and* $\phi \rightarrow e^+e^-$

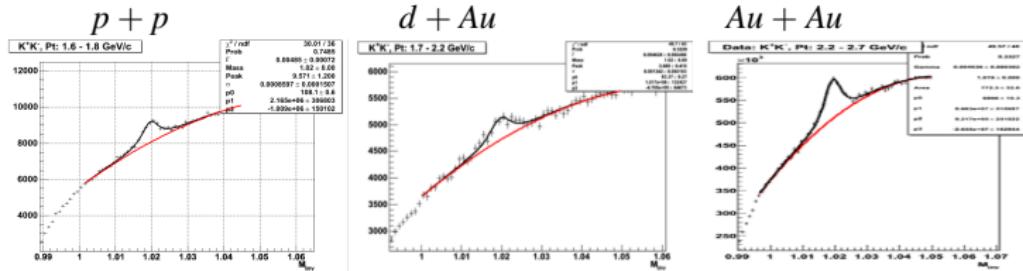
$\phi \rightarrow K^+K^-$ measured using two methods $\phi \rightarrow e^+e^-$

- No Kaon identification
- One Kaon identified

$\phi \rightarrow K^+K^-$ and $\phi \rightarrow e^+e^-$

$\phi \rightarrow K^+K^-$, $\sqrt{s_{NN}} = 200$ GeV)

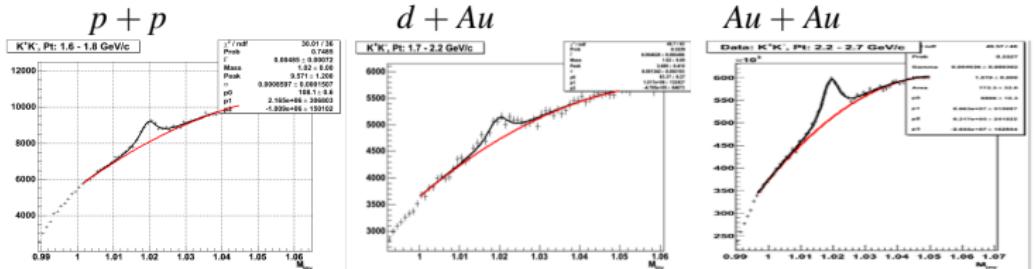
No Kaon ID



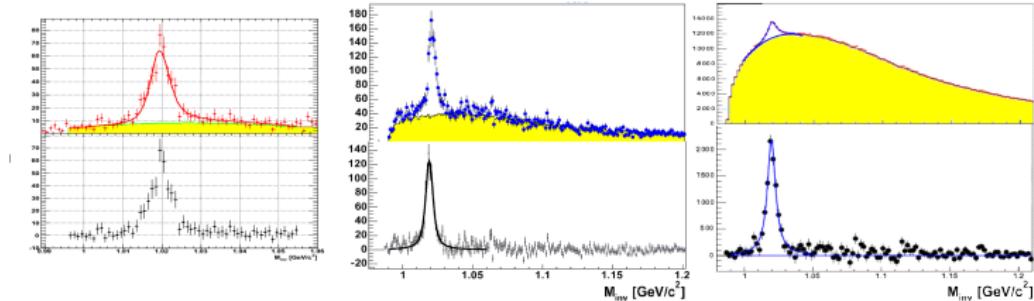
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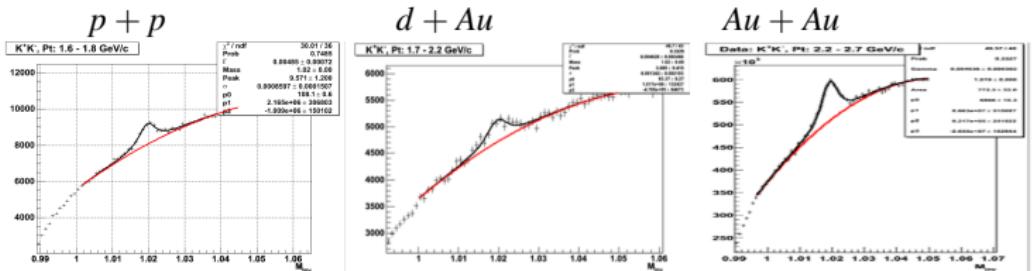
Two Kaons ID



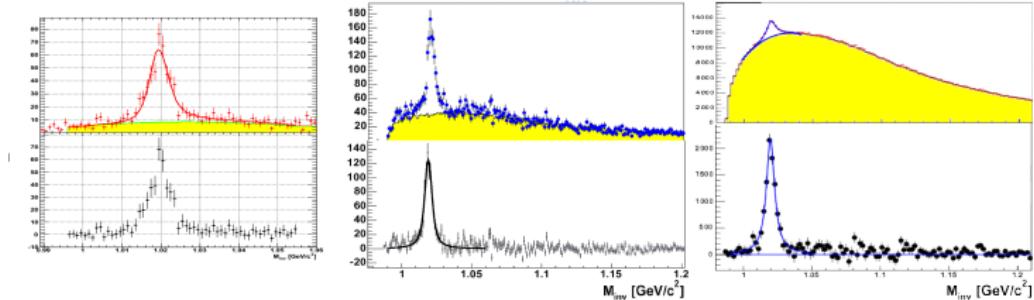
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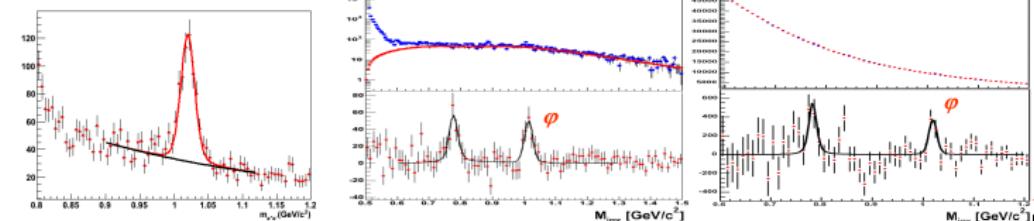
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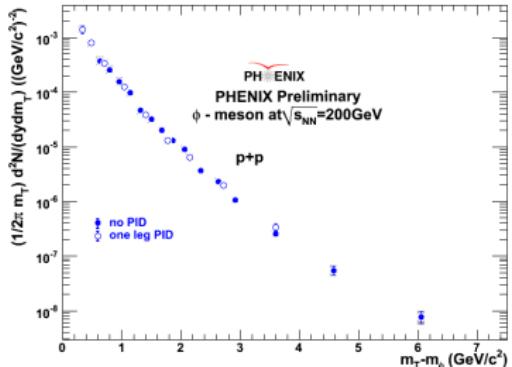
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$\phi \rightarrow e^+e^-$



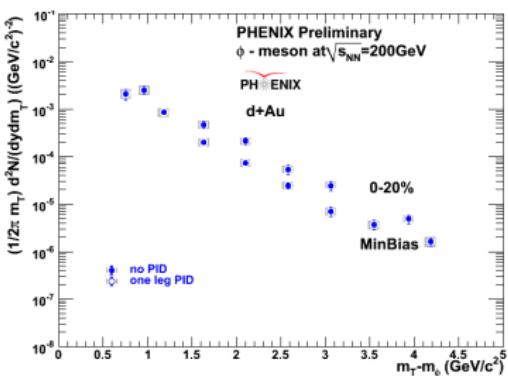
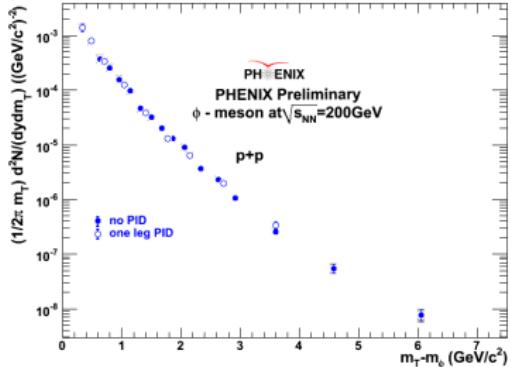
$\phi \rightarrow K^+K^-$ spectra



Data Set

- p+p 200 GeV: new Run5 measurements
- d+Au 200 GeV: Run3.
- Au+Au 200 GeV: Run4
- Two independent analyses agree in Au+Au and two in p+p.
- extended p_T coverage.
- Au+Au 62.4 GeV: Run4

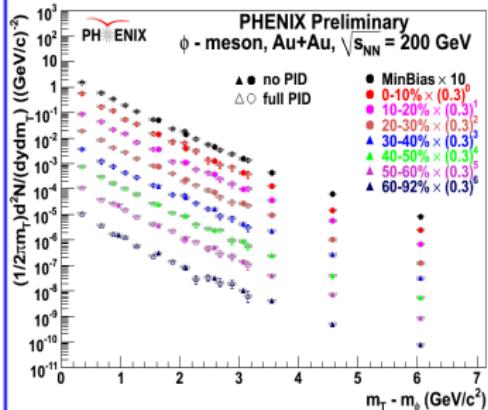
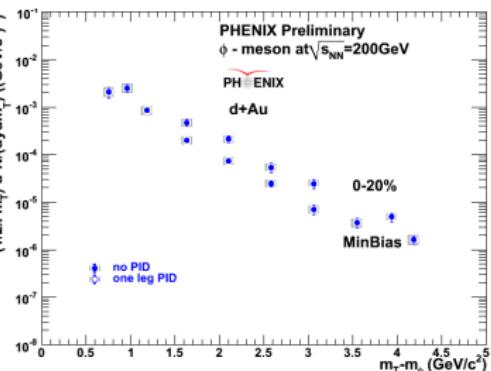
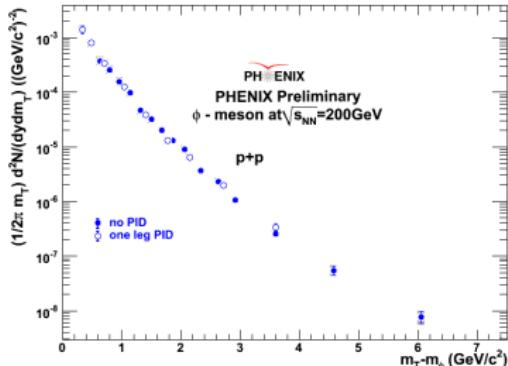
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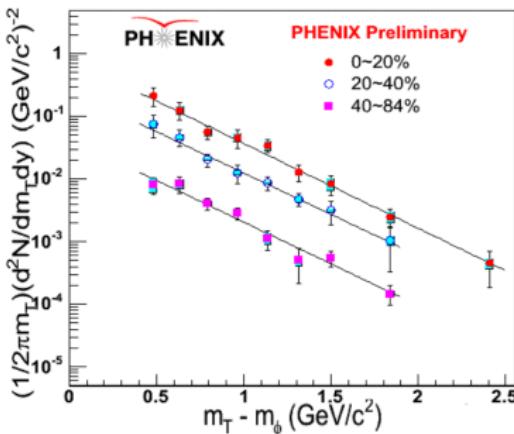
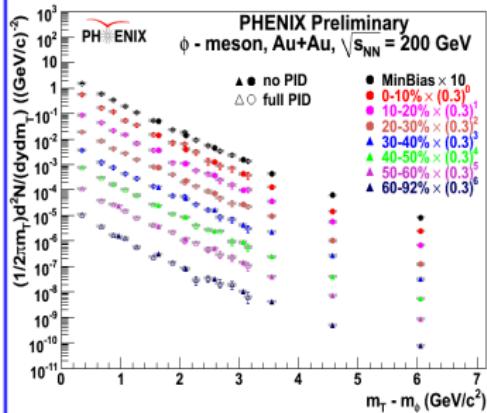
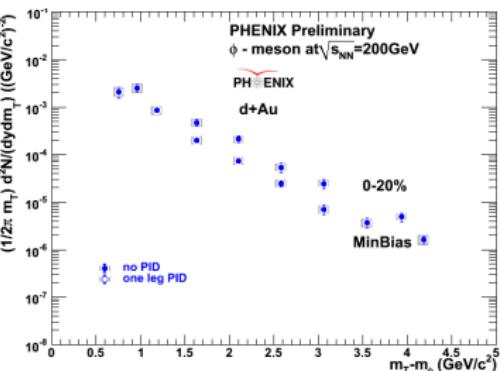
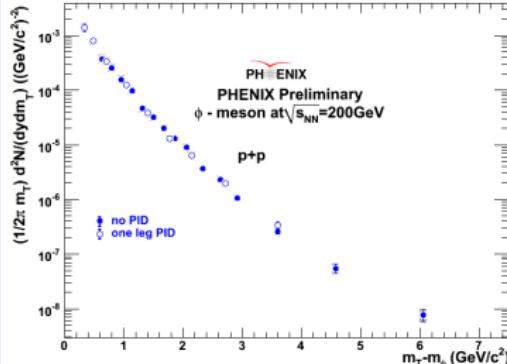
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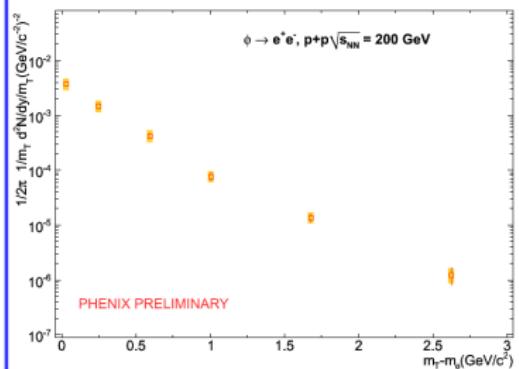
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$\phi \rightarrow e^+e^-$ spectra



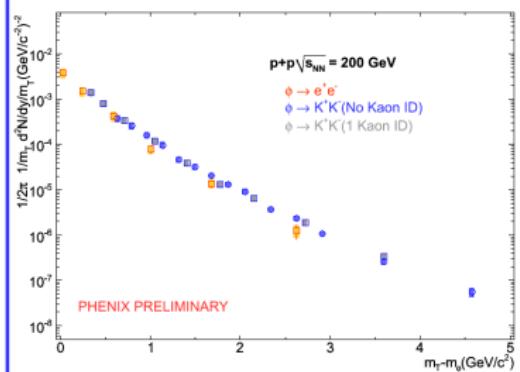
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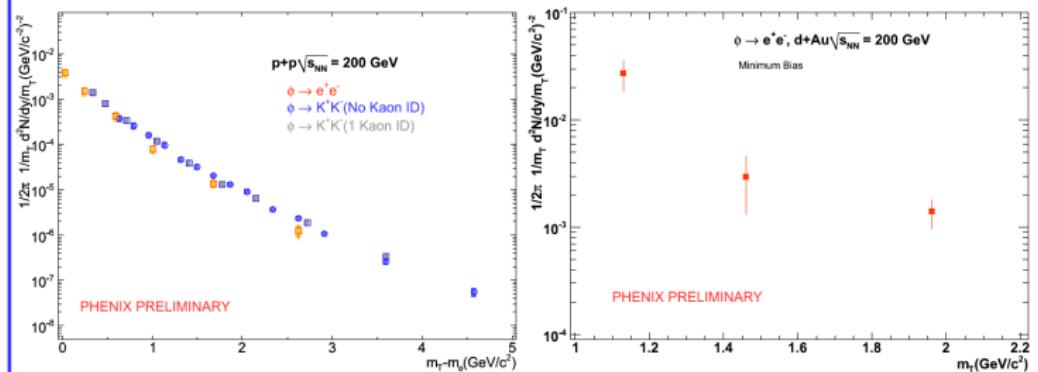
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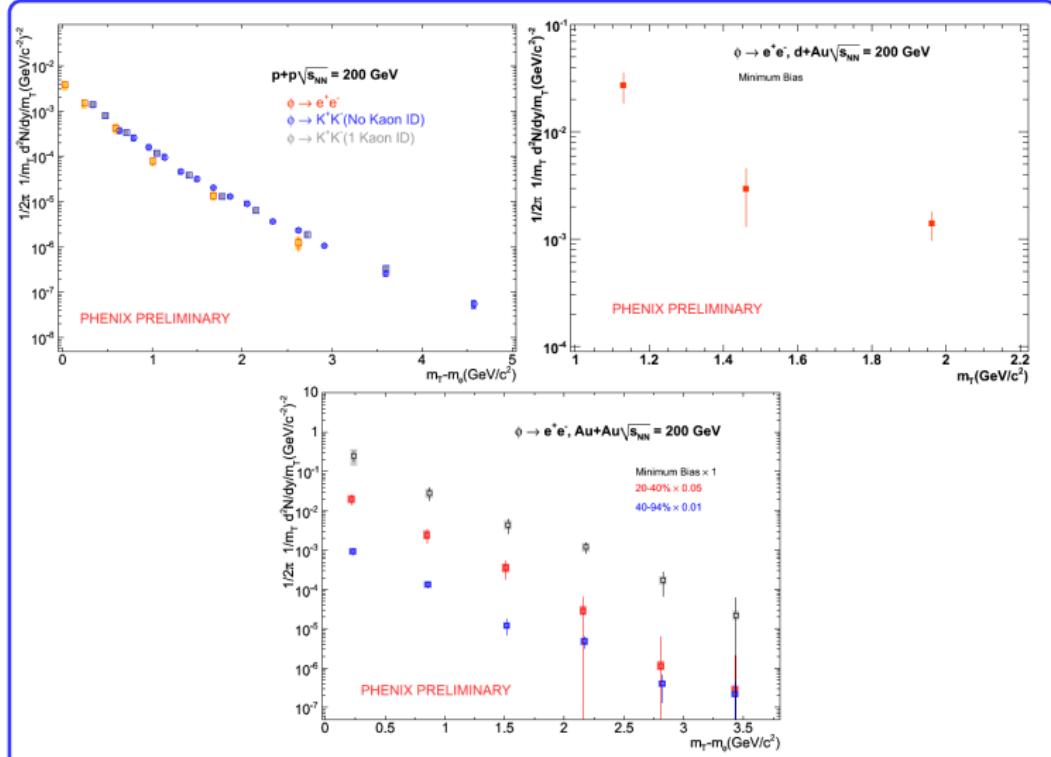
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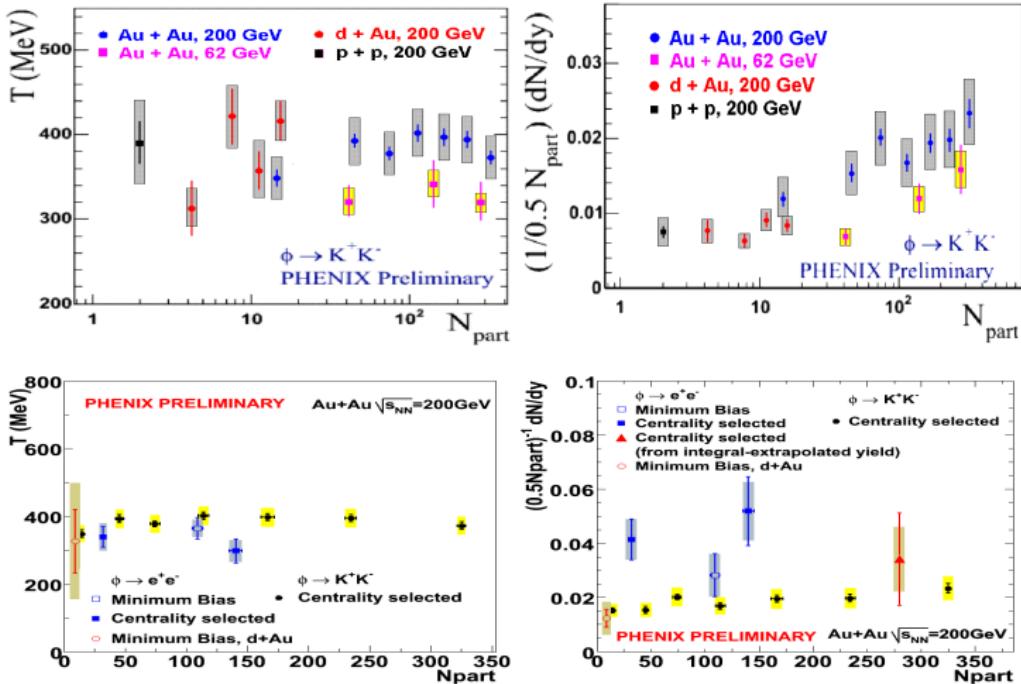
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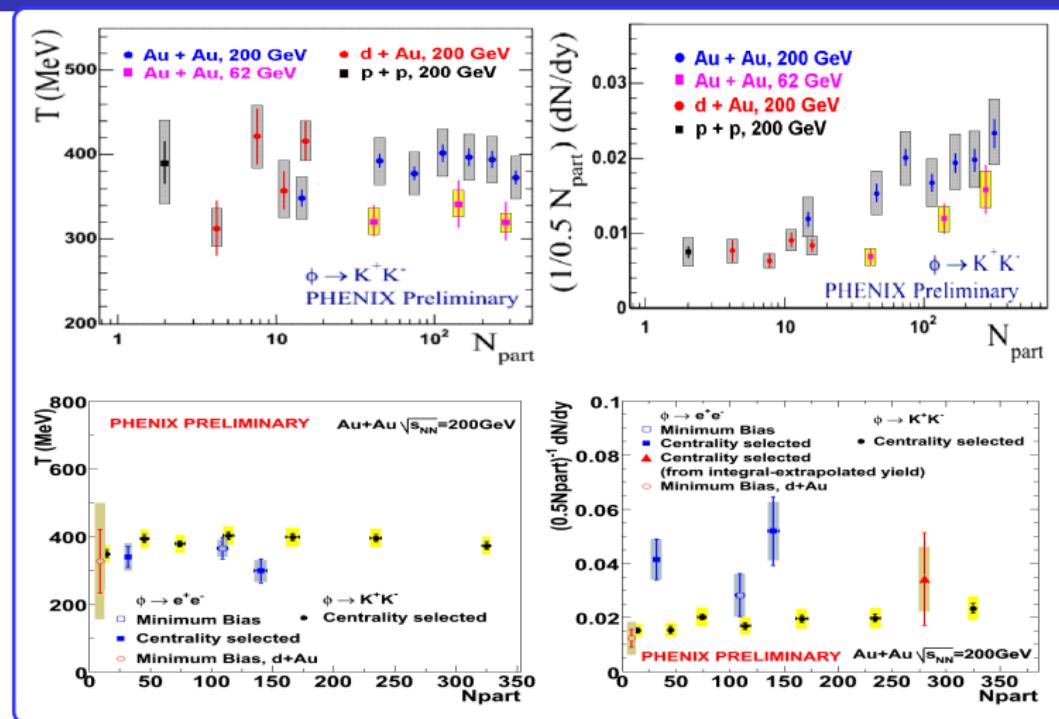
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ϕ -meson yield and temperature



- Temperature \sim same @ 62, 200 GeV, constant with N_{part}
- Yield grows with $\sqrt{s_{\text{NN}}}$ and Centrality.
- Slope measured with leptonic channel is consistent to the Hadronic mode.
- Yield in e^+e^- channel seems higher, compared to K^+K^- channel, but errors bars are large to make any conclusive statement.

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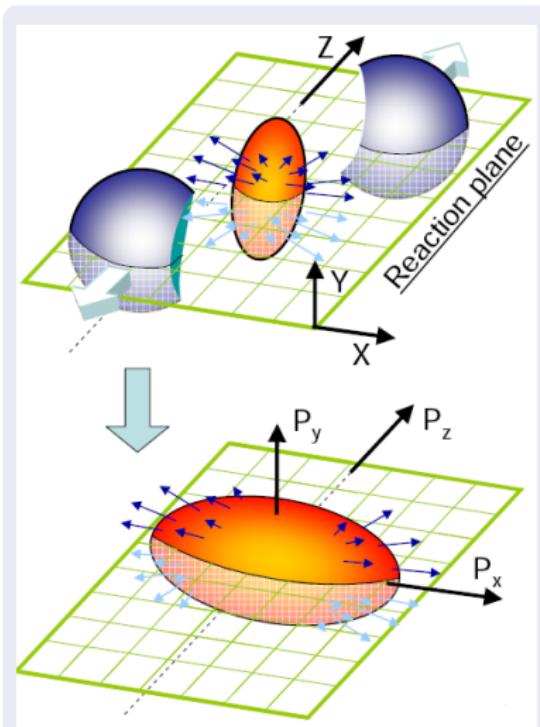
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Elliptic Flow

Elliptic flow v_2

- The measured v_2 reflects the dense matter created in the initial stages of heavy-ion collisions.
- v_2 is a measure of anisotropy of particles in momentum space, produced during the early stages of heavy-ion collisions. Non-central A+A collisions result in an azimuthal anisotropic distribution in co-ordinate space. Due to pressure gradients and interactions among the particles, the initial space anisotropy gets converted to momentum anisotropy.
- The signal is self quenching \Rightarrow **early time observable**.
- v_2 is the 2nd coefficient of an azimuthal Fourier expansion of the transverse momentum spectrum around the beam axis.

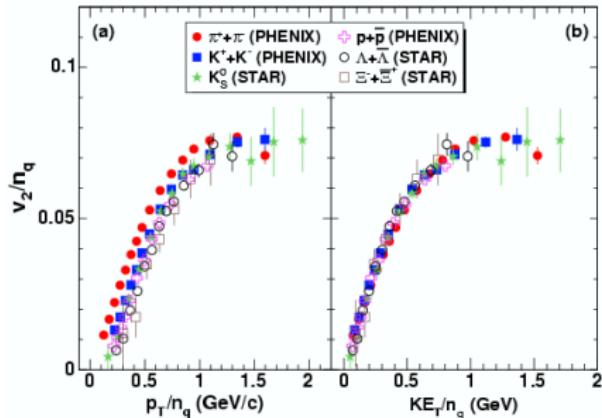
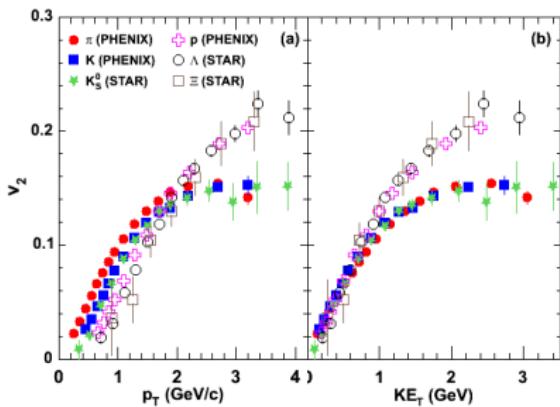
$$E \cdot \frac{d^3N}{dp^3} = \frac{1}{2\pi} \cdot \frac{d^2N}{dp_T dy} \cdot [1 + 2\nu_1 \cos(2\phi) + 2\nu_2 \cos(2\phi) + \dots]$$
$$\nu_2 = \langle \cos(2\phi) \rangle$$



*v*₂ of Baryons and Mesons

π , K, p (PHENIX) PRL 98, 162301 (2007)

K^0_s , Λ (STAR): PRL 92, 052302 (2004) Ξ (STAR): PRL 95, 122301 (2005)

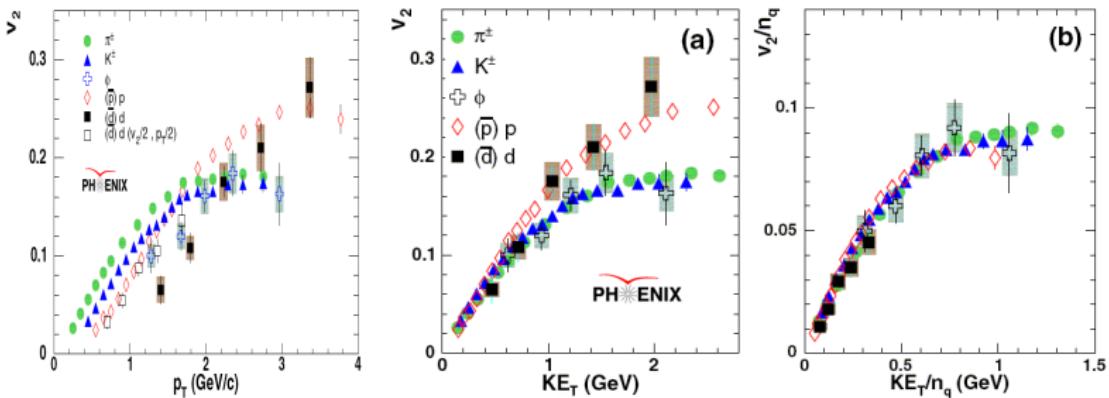


- At low transverse momentum ($p_T \leq 2.0$ GeV/c), v_2 is consistent with the mass ordering expected from hydrodynamics.
- Results are consistent with Quark number + KE_T scaling.

- The systematic measurements of v_2 for the strange hadrons Λ , K_s^0 , Ξ and Ω suggest that collectivity is developed at the partonic stage at RHIC.
- This concept of partonic collectivity can further be strengthened if ϕ -meson flows like the other mesons.

v_2 of ϕ

Au+Au $\sqrt{s_{NN}}=200\text{GeV}$



Phys. Rev. Lett. 99, 052301 (2007)

- ϕ -meson shows a significant flow, with a similar trend as that π^\pm and K^\pm at higher p_T
 - consistent with universal scaling of v_2 per constituent quarks.
 - flow is developed at the partonic level at RHIC.
- ϕ is created via coalescence of thermalized quarks in Au+Au

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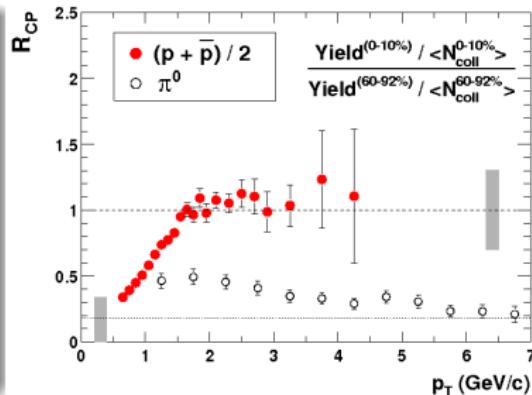
Nuclear Modification Factor

The nuclear Modification factor R_{AA} is

$$R_{AA}(p_T) = \frac{d^2N^{AA}/dp_Tdy}{\langle n_{coll} \rangle \cdot d^2N^{pp}/dp_Tdy}$$

R_{cp} is the ratio of central to peripheral yields scaled by their respective N_{coll} value.

$$R_{CP}(p_T) = \frac{N_{coll}^{peripheral}}{N_{coll}^{central}} \cdot \frac{d^2N_{AA}^C/dp_Tdy}{d^2N_{AA}^P/dp_Tdy}$$



Phys. Rev. Lett 91, 172301 (2003)

- Pions are suppressed in Central Au+Au collisions @ 200 GeV
- Protons show no suppression at 2-4 GeV/c.
- The suppression pattern depends on particle species.

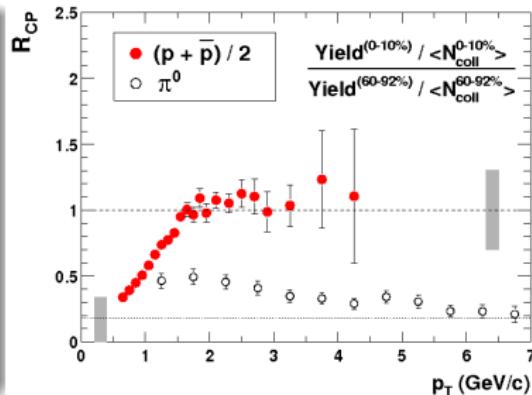
Systematic measurements of R_{AA} and R_{CP} for various particles helps to understand the nuclear medium effects on hadron production.

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Phys. Rev. Lett 91, 172301 (2003)

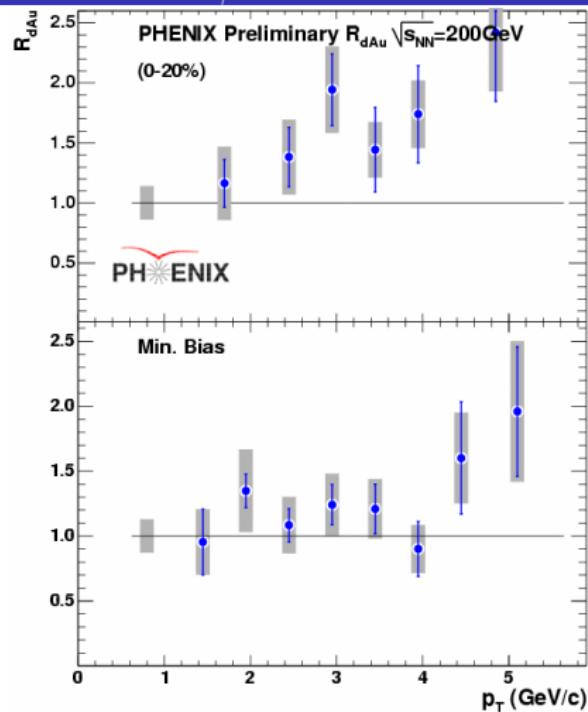
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ϕ -Nuclear modification factor

in d+Au 200 GeV

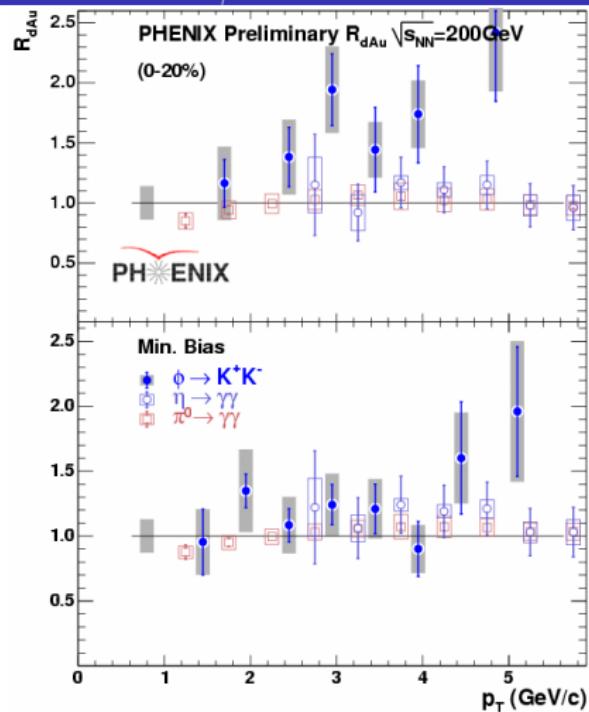
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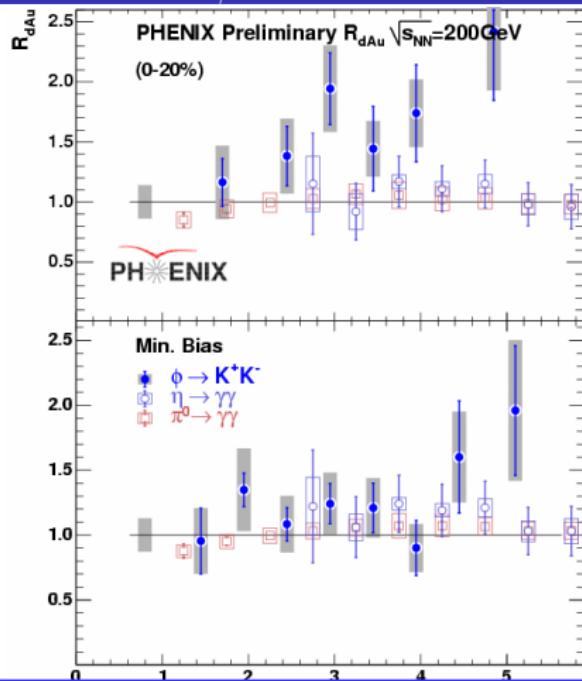
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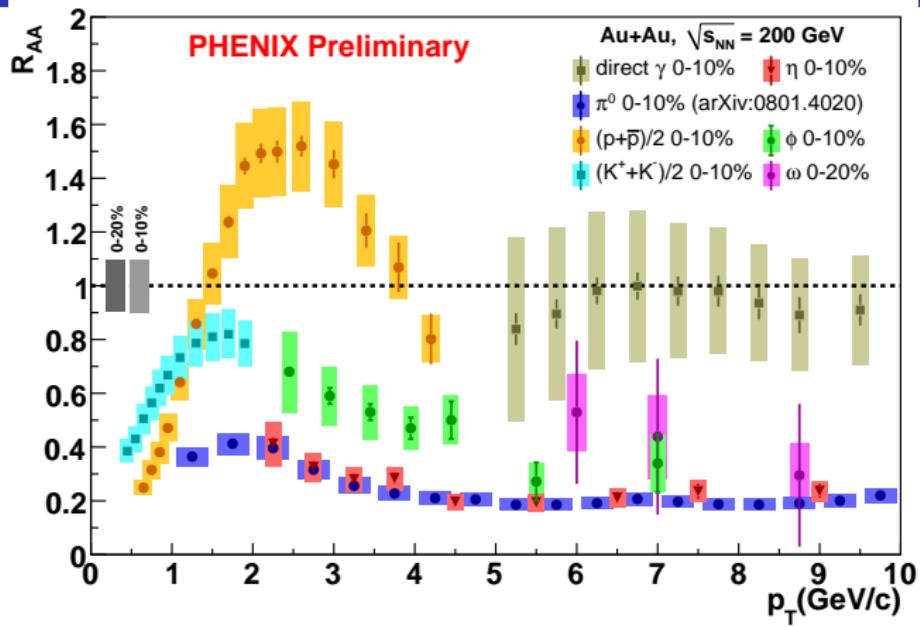
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- ϕ is not suppressed in d+Au
- R_{dA} of π^0 , η is consistent with 1. ϕ enhancement in 0-20%?
- Large error bars leave some room for Cronin enhancement

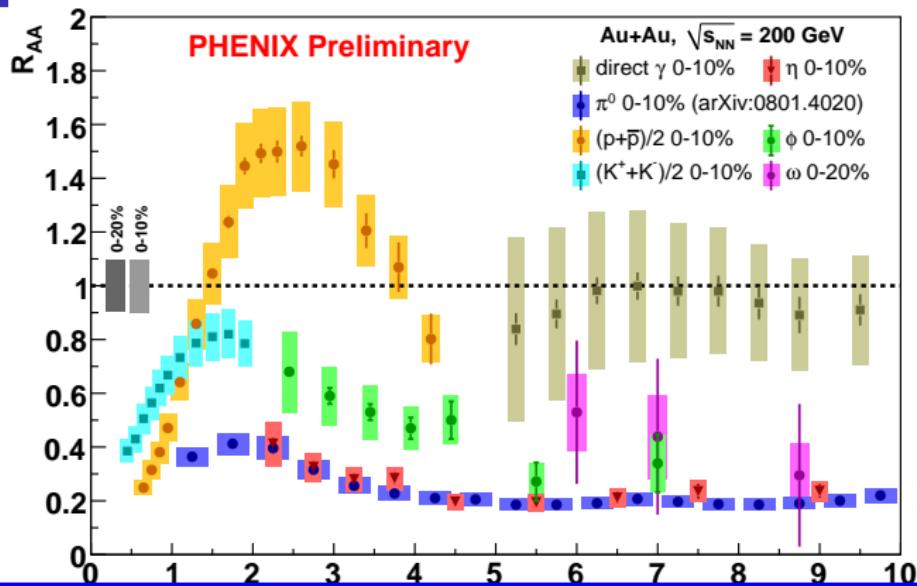
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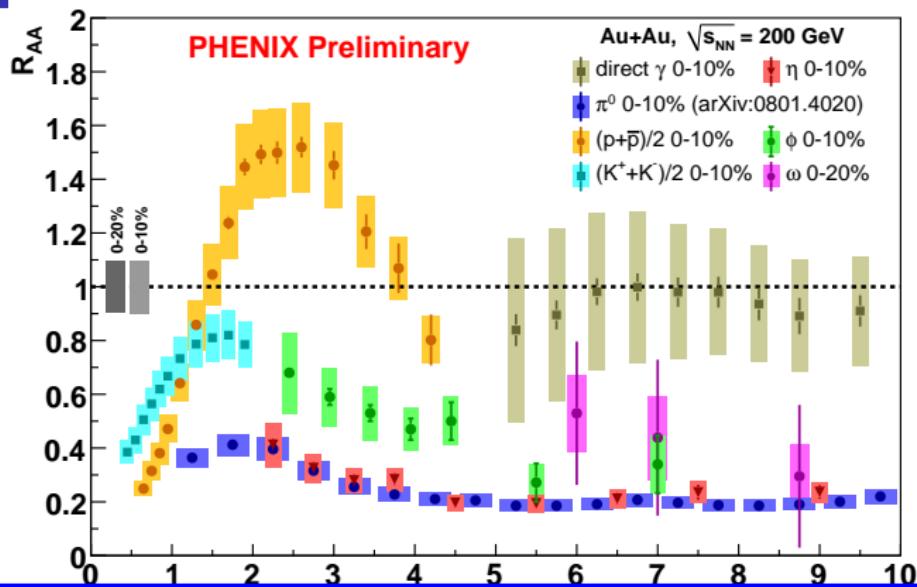


The known fact:

Hadron suppression patterns do not depend on the mass of the particles, but they are sensitive to the number of valence quarks.

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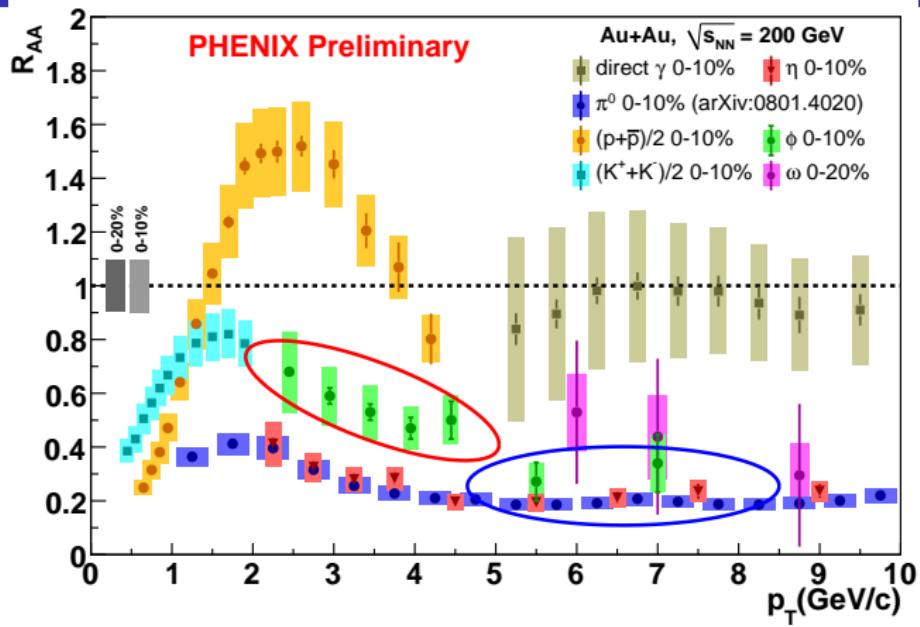
ϕ meson does not fit into common picture...

It is less suppressed than π^0 and η at intermediate p_T .

Does suppression depend on quark flavor composition?

ϕ -Nuclear modification factor

in Au+Au 200 GeV



At high p_T : the ϕ - suppression level is similar to that of η and π^0

At Intermediate p_T : the suppression pattern is different.

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PHENIX has measured ϕ -meson in $p + p$, $d + Au$ and $Au + Au$ collisions $\sqrt{s_{NN}} = 200\text{GeV}$ by K^+K^- and e^+e^- decay modes.

The measurements using K^+K^- decay channels are complete in all systems. The leptonic channel measurement suffer due to combinatorial background and statistics in $Au + Au$ and $d + Au$.

The measurements using K^+K^- channel are extended to higher p_T in $p + p$ and $Au + Au$.

The ϕv_2 is consistent with other mesons and follows Quark number $+KE_T$ scaling.

In $d + Au$, no suppression is seen, but large error bars make room for Cronin enhancement.

The R_{AA} of ϕ -meson in $Au + Au$ shows similar suppression pattern to that of π^0 and η at high p_T , but at intermediate p_T , the suppression pattern is different.

does quark flavour plays a role ?

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Back ups

$\phi \rightarrow K^+K^-$ spectra

